Architectural Science Review
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/tasr20

A Critique of the Passive Zone Concept for Energy Conservation Design Tools

Richard Hyde [a] & Aldomar Pedrini [b]
[a] Dept. of Architecture , The University of Queensland , St Lucia, QLD, 4072 E-mail:
[b] Dept. of Architecture , The University of Queensland , E-mail:
Published online: 11 Oct 2011.

UDC: 620.91(213) Keywords: Energy conservation;
Passive zone concept

A Critique of the Passive Zone Concept for Energy Conservation Design Tools

Richard Hyde* and Aldomar Pedrini**

The use of design tools in architectural design is common place. Yet, in recent years the need has arisen to provide design tools to assist with the evaluating the energy usage of buildings. A number of tools are available for this type of work. Unfortunately, many of these tools are inappropriate for integration in the architectural design process. The research described here reports development work on a lighting, thermal and ventilation tool for use at the conceptual stage in the design process. The main contention is that this type of tool is crucial to effective passive low-energy design as it is difficult to integrate energy saving feature at later stages in the design process. Part of this work has necessitated a critique of the concept of the passive strategies for non-domestic buildings; this is an important element in assessing the energy contribution of the external environment to the building.

Introduction

Research work has been under way to develop an energy conservation design tool for assessing the environmental impacts of non-domestic buildings in warm climates. In this case energy -use is taken as an indicator of environmental impact and the toll is aimed mainly for architects.

This tool is called the Lighting Thermal and Ventilation (LTV) architectural design tool [1]. During the development of this tool the main question that arose concerned the form of the tool. It became clear that to be most effective for giving the architect feedback it must be linked to the consequences of the building design factors that influence energy consumption. It therefore is aimed at modelling the energy consequences of using climate responsive design strategies in the building design. Further more most of the literature points to connecting energy tool such as LTV with the design process. It is widely acknowledged that 'the best opportunity for improving a building's energy performance occurs early in the design process when basic decisions are made' [2].

Moreover, the penalty for not addressing climatic responsive design issues early in the process is that 'opportunity will be lost to make significant savings by relatively simple adjustments to the design. Increasingly sophisticated or costly efforts are needed to save energy [2].

Whilst the design process can be seen as a series of stages, it might be easier to consider these as activities. Of most interest is the conceptual design stage where basic climatic responsive strategies are used. In large commercial non-domestic buildings this involves the planning, layout and thermal zoning of the building. Thermal zoning is a key concept for assessing the thermal response of the building. It is defined as the relationship of the spatial organization of the building and the influence of environmental factors. Thermal zoning is the subdivision of spaces inside the building that have

* Richard Hyde, Dept. of Architecture, The University of Queensland, St Lucia, QLD 4072 r.hyde@mailbox .uq.edu .au
** Aldomar Pedrini, Dept. of Architecture, The University of Queensland, alp4@bne.comcen.com.au

varying thermal temperatures. Zones vary with orientation and with exposure to environmental conditions.

A common nomenclature in cool climates is to use two main zones, the **passive** and **non-passive** (active) zone. 'Passive zones can be day lit and naturally ventilated and make use of solar gain for heating. Non-passive zones have to be artificially lit and ventilated' [3].

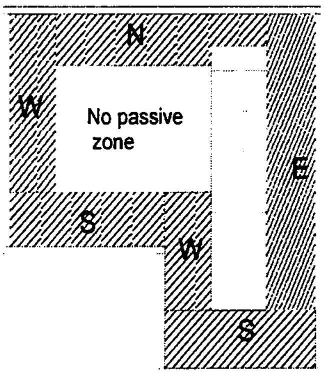

Figure 1: Passive active zone concept, the passive zones are shaded. This concept originated for temperate climates.

The importance of this description is that the passive zones consume less energy due the use of natural energy than non-passive zones, which use man-made energy ie. electrical energy. Therefore a basic climate responsive planning strategy is to make these passive zone as large as possible to reduce energy consumption.

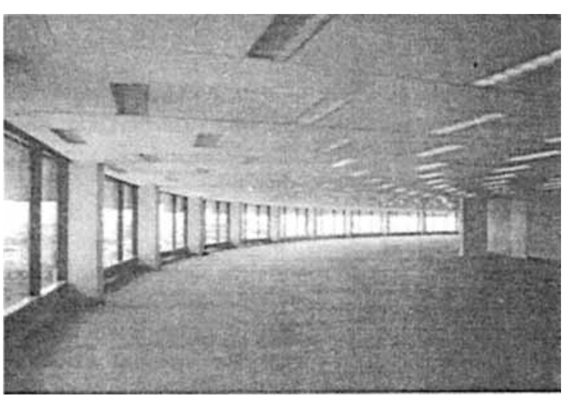

Figure 2: Interior section through a high rise building

Interestingly this is a fundamental concept for the design of energy tools yet at present little work has been carried out to validate this concept. Indeed it seems to be a research construct, which has been derived basically by rule of thumb. For example the extent of the passive zone is deemed to be twice the ceiling height so for a ceiling height of 3 m this gives a depth of 6m [3]. In addition this concept appears to have originated in temperate climates.

The question arises as to the nature of the passive and non-passive zone for warm climates. It may be larger for warm climates due to higher levels of day lighting [4]. This is further complicated if the theory as described in Figure 1 is matched with practice as seen in Figure 2. Figure 2 shows an internal photograph of a high rise building in Sydney. The electric lights are turned off and there is no furniture. There are high glazing ratios and exterior shading which is used to minimise thermal gains for direct sunlight. The line of the passive zone is not as clearly determined as in Figure 1. There is not a defined boundary rather daylight penetrates further than twice the ceiling height from the facade, also it is moderated by the shading, natural ventilation is not effective due to the sealed windows. Therefore, the passive zone concept in this context seems more complex than originally imagined in the temperate climates.

This paper examines these issues from a theoretically and experimentally stand point. The first part includes a theoretical discussion of climate responsive design strategies to determine the concepts for zoning in warm climates; the second part describes experimental work to establish the nature of the passive zone for warm climates. The final section provides a discussion of the results.

Table 1: The climate responsive design strategies

Planning strategies:	*Façade strategies:*	*Service strategies:*
plan/ room depth	ceiling height	air conditioning
service spaces zoning	orientation	electric lighting
functional zoning	window area and position	natural ventilation
thermal zoning	thermal defence	
	solar shading and light guiding	
	natural lighting	

Part 1: Climate Responsive Design Strategies

A review of the passive, low energy design principles used in non-domestic buildings revealed the following factors important in warm climates. These are framed as design strategies that can be used by architects to reduce energy consumption (see Table 1). For the purpose of the study these strategies are used as variables that can be manipulated in a work-back process.

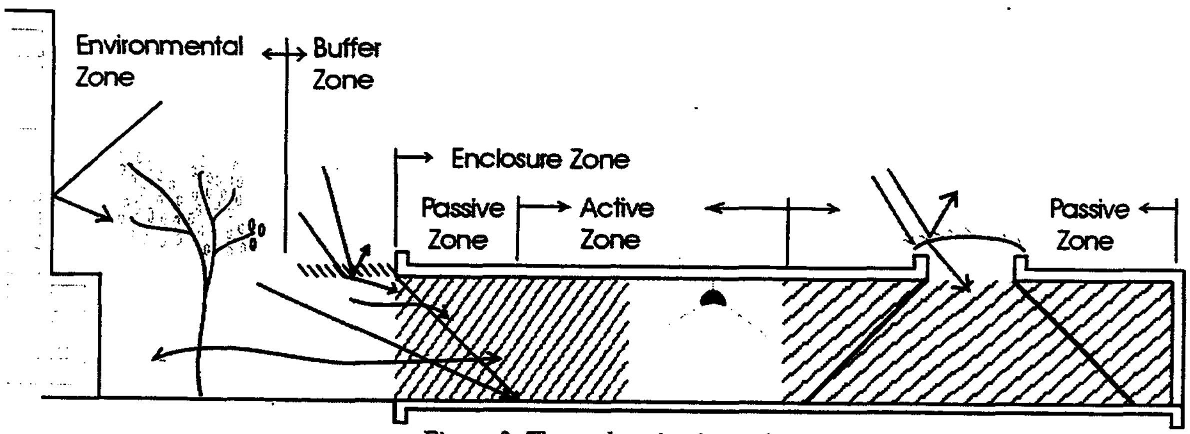

Figure 3: Thermal zoning in section

This involves generating a number of possible design scenarios an architect may take and find the energy consequences. Architects tend to evaluate design concepts in terms of the plan and section of the building.

A hierarchy is found in the decision making process which relates to priorities designers have in the design process. For convenience, first order decisions are those that relate more to the planning decisions whilst second order are those in the section. Second order decisions examine the relationship generated by the façade. This involves examining relationships between solar shading window size, lighting and energy. It is common practice for buildings in warm climates to apply this strategy in favour of reducing thermal loads through the façade by over shading. Yet this can mean higher electrical lighting consumption. The loss of natural light is also a reduction of amenity to users.

Earlier models have recognized the significance of the effect of natural light on reducing electrical consumption [5, 6] but there has been little work into examining this relationship for subtropical and tropical climates. The outcomes of this work show the optimum shading and window wall ratios for design related factors [7].

In the study reported here the first order involved study of the planning strategies used to improve energy efficiencies. Previous work has established that considerable savings in energy use can be achieved by planning the building to achieve optimum plan depths, environmental zoning of spaces, ceiling height and orientation. This is an important area for saving energy, 30% savings in energy use can be achieved by using this strategy alone [8].

To assist architects in assessing the energy consequences of planning decisions the concept of the passive zone has been extended for a warm climate[6]. In this approach a variety of further zones have been identified. These can be established for both inside and outside the building from the line of enclosure to control the external climate.

These are shown in Figure 3 and described as follows,

External Zones:

- Environmental zone: micro climate of the site
- Buffer zone: microclimate created by the building

Internal Zones:

- Enclosure zone: internal climate, immediately adjacent to the line of enclosure

- Passive zone: the area defined in plan to receive a significant contribution from the external environment for heating, lighting and ventilation. The convention is to use a dimension equal to twice the ceiling height to define the extent of this zone from the façade
- Non-passive zone: the area defined in plan and which receives an insignificant contribution from the external environment for heating, lighting and ventilation.

Table 2 Characteristics of the test cell

Characteristics	**Value**
Size	Dimensions: width = 10m, ceiling height = 3m, variable depth
Orientation	North
Weather	Brisbane TRY
Operational schedule	Lights and air conditioning working between 8 am and 6 pm
Lights	320 Lux in work plane, with light power density equal 10 W/m
Daylight control	Electric lights are either off, one third-on, two third on or fully-on
Work plane height	Height from floor: 0.765m
Reflectance	Wall: 0.5; floor: 0.2; ceiling: 0.8
Window,	Window width = 10m (frame width 0.051m), single clear glazing 3mm, light transmission 0.898, U-factor (center of glass) = 6.31 W/m/°C; window front facade: 10 m. No shading was provided to the window
Envelope properties	Walls, floor and roof thermally insulated
Air conditioning	Packaged, EER (energy efficiency ratio) = 2.638 W (cooling)/W (consumption); cooling set-point: 22°C

For quantitative assessment the crucial design variables can be related to the passive zone and therefore to this end a study using series of computer simulation exercises was carried out using DOE 2. It is acknowledged that the qualitative variables concerning lighting or other factors were not addressed in this study ie. factors such as glare.

The main aim of the study was to examine the extent of the passive zone for warm climates. A 'rule of thumb' has been established for cool climates. The extent of the passive zone is function of room depth and the ceiling height, where the passive zone is seen as twice the ceiling height. Thus for a ceiling height of 3meters, the passive zone extends 6 meters to towards the interior, at 90 degrees from the façade.

Part 2 Experimental work

The extent of the passive zone is controlled by two main sets of factors:

- Zone planning characteristics - the room depth, that is the depth from facade and the orientation
- Façade and section characteristics- solar shading, electric lighting, the level of transparency in the facade to provide daylighting.

The main goal in the study was to identify parameters to define an optimum room depth that gives minimum energy consumption. The analysis consisted of varying the room depth and different amounts of transparency in the envelope. A test cell was developed to examine this relationship. This was used to simulate energy performance by using a computer simulation tool.

Test Cell

For the study the test cell was set up in DOE 2 [9]. The main characteristics are used in the cell are as follows, more detailed characteristics of the test cell are shown Table 2.

- room size of 10 x 20 m
- floor to ceiling height 3 meter
- insulation is used in the wall, floor and ceiling to prevent heat gain
- cooling loads from people and equipment are not included
- The windows are constructed with clear glass, sill height 1.0 m, width 10 m, and height 1 m.

Façade and sectional characteristics

One of the main issues in facade design is to optimise the relationship be window size, shading and daylighting. Lack of shading to windows will increase thermal loads whilst overshading will increase electrical light consumption.

Experimental work was carried out to determine optimum facade characteristics for various room depths.

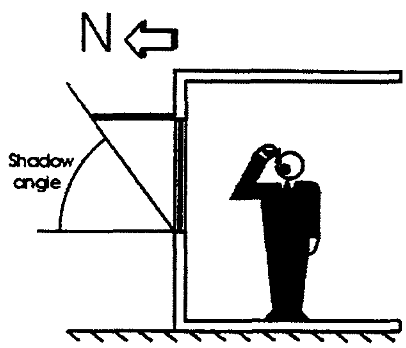

Figure 4: Shadow angle definition

First a methods of manipulating solar shading was developed so that this could be achieved in a systematic way. As shown in Figure 4, the angle between a horizontal plane and the line that links the base of window and the extreme of the shading overhang defines the extent of shading.

The second issue is the location of the window. A number of additional assumptions were made regarding nature of the test cell used for the study with regard to these choices.

- The window was designed as a strip window, which has the same width of the facade. This gives a greater uniformity of the light distribution for a given distance from the facade.
- A working plane of 0.8 meters was used as this is common practice for office buildings
- The optimum windowsill height was set at 0.8 meters. The lighting gain below this height is not significant. Yet, the heat gain is significant and would increase the thermal gains to the space.

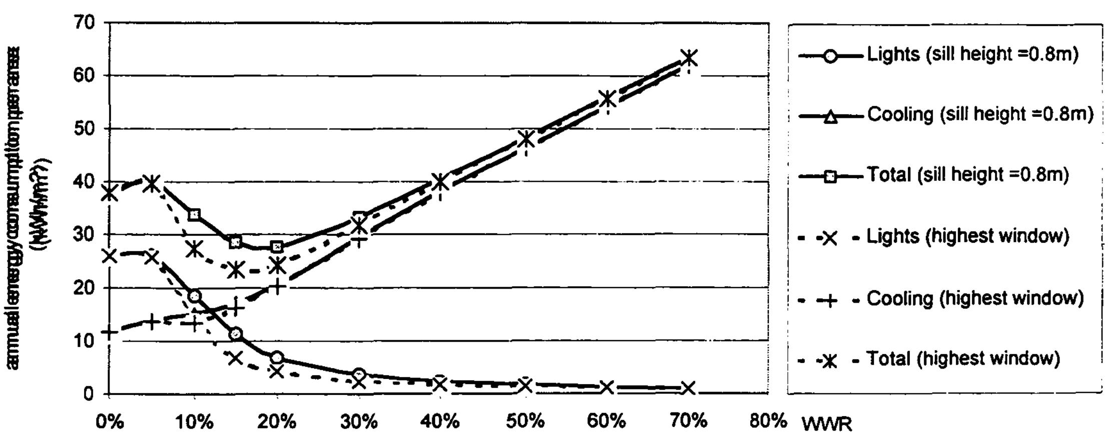

Figure 5: Analysis of the window location on façade.

In this case as the window wall ratio varies the window does change in height but in width. Thus with small window wall ratios the window geometry will be narrow and thin. One problem emerged from these assumptions; the location of small windows of say 0.3m with a sill height of 0.8m can be problematic. The window location should be as high as possible to optimise the daylighting. In the Figure 5 a comparison of the performance of the window with a sill height equal to 0.8m and with the highest window height is shown.

The results confirm the above problem: the higher the windows the more lighting efficient than any other position. The difference in performance is almost 20%. Therefore, in the test cell sill heights were kept constant at 0.8m and window wall ratios varied in width.

Zone planning characteristics

A further set of simulations was carried out manipulating the main variables to test the effects of planning decisions on energy consumption. The range of options varies from 4 to 20m in the depth of zone. One-meter increments in plan depth were used as well as 10 per cent variations in the window wall ratio. The results of this study are plotted in Figure 6. Optimum energy consumption is shown for varying room depths, also the optimum window wall ratio. The following observations can be made:

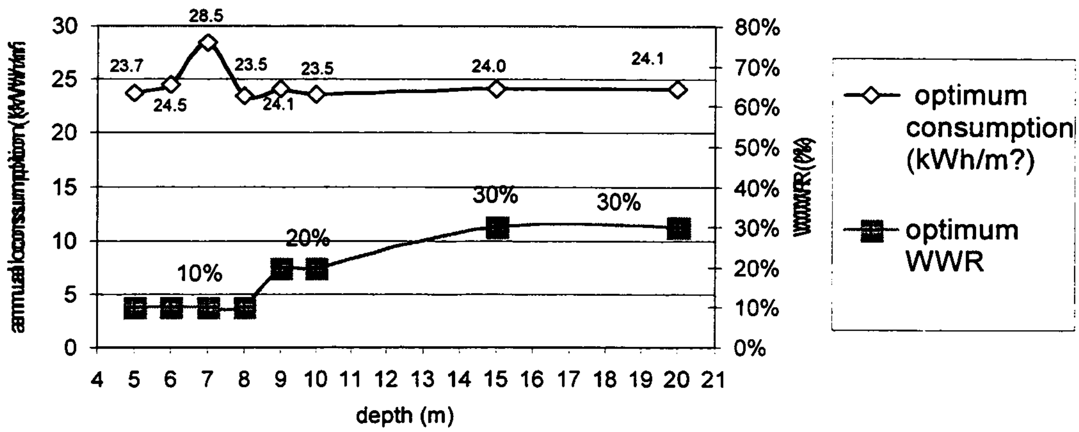

Figure 6 Different plan depths the optimum energy consumption for the window wall ratio (WWR) can be found.

- Without shading to the windows the optimum WWR is between 10 to 30 percent. Thus, for a northerly facade, small windows between 3 and 9m2 in area for every 10 meters of linear length are appropriate.

- As the room depth is increased, the larger window wall ratio of 30 percent is appropriate, as the depth is reduced a smaller ratio of 10 percent is appropriate.

The optimum room depth is 8 meters with lowest consumption using a 10 percent WWR.

Clearer evidence of this is seen in Figure 7. In these graphs the relationship to WWR to energy consumption is shown for different room depths. If the worst optimum performance is ranked, the most problematic is the room with a depth 7m and with a WWR 20%.

The second worst is the room with a depth of 6m. The best performances are the rooms with 8m and WWR 10% and the room with 10m and WWR 20%. These results can be used to identify a reasonable optimum depth for passive zones the choice would be 8m.

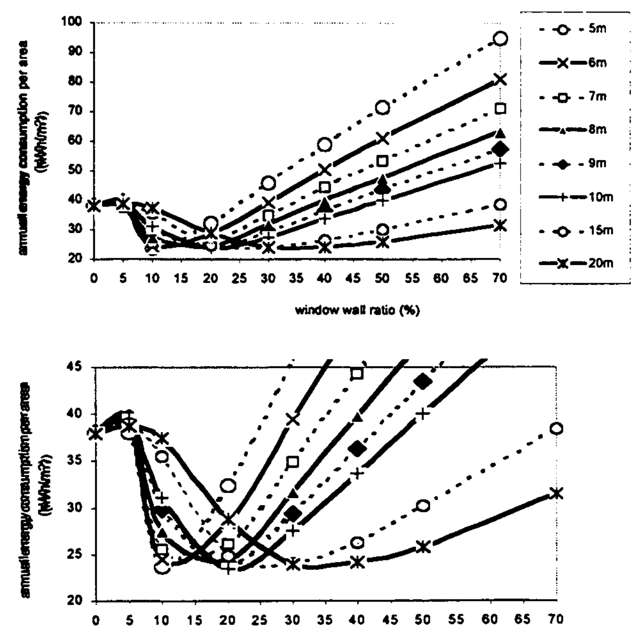

Figure 7: Top: annual consumption per area for different room depths. Bottom: details of lower consumption area.

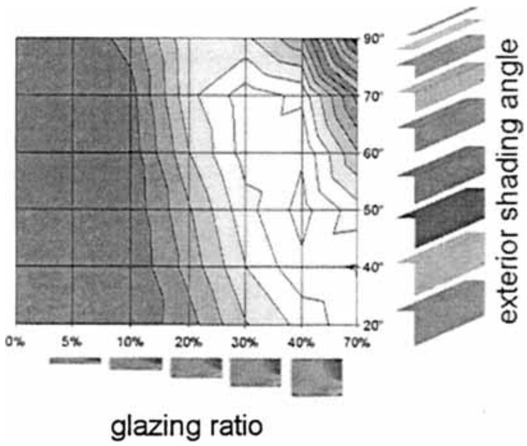

Figure 8: Graphical tool for assessing thermal zoning strategies

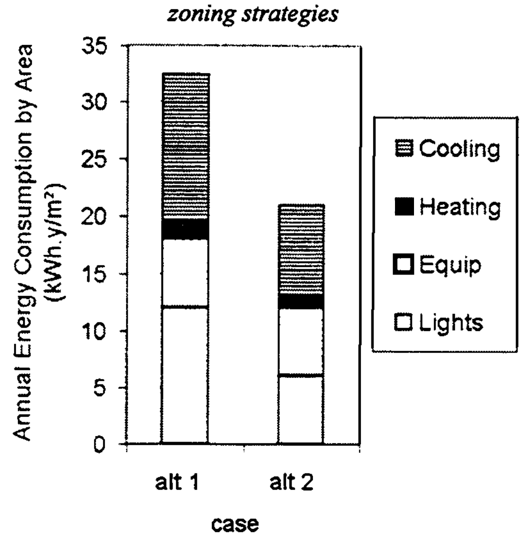

Figure 9: Alternatives comparison of plan and section options

Part 3 Discussion

From these results it is clear that the assumptions concerning the size of the passive zone found in European climates is different for subtropical climates such as Brisbane. The higher levels of solar gain and availability of daylighting means that the optimum plan depth can be increase to 8 meters with a lower wall to window glazing ratio. In this study shading was not considered although the method for assessing this has been developed. Further work has been carried out to assess optimum shading, window wall ratios and plan depth [9]. Further more a more subtle definition of the passive zone emerges which is more dynamic, related to sectional information rather than plan information. In this conception rather than try and make hard definitions of zoning, it seems appropriate to use this type of information for making the strategic design decisions.

One further outcome of this is that it is possible to use this information in a number of ways. The earlier definitions of the passive zone are aimed at providing a method of assessing plans to give summative information regarding energy use. The contention here is that this summative information is less useful per se except for overall bench marking purposes. Formative information from this type of graphs enables the selection of optimum window wall ratios for room depths or visa versa.

Further more benchmark figures for building types can be set and optimum design variables selected to meet the benchmark. Thus the benchmark for northern orientated facades may be 30 kWh/m2.

A range of window wall ratios and rooms are therefore available to meet this standard. This gives boundaries in which the designer can work. This flexibility can begin to intellectualise the design process so that choices available to designer can be clearly indicated and the consequences of choices articulated. It is clear that this information can be integrated into a graphical tool, which gives visual information of the consequences of selections made by designers as shown in Figure 8 and 9. In Figure 8 the results from a three-dimensional graph which plots plan depth, shading angle and glazing ratio is shown. In this example the graph is cut through in the horizontal plane for each plan depth. Thus in Figure 8 a contour map is give for the 8 m plan depth which shows optimum shading and glazing ratio.

If this graphic information is integrated with the passive zone concept, then optimum energy conservation, shading, angle and glazing ratio can be selected for each zone. It can then be carried out for each orientation and the total energy consumption figures can be computed as shown in Figure 9.

Conclusions

Further work has integrated this approach into and the energy conservation tool, LTV for Brisbane climates using ACCESS software. It is anticipated that this will facilitate Internet publication for on-line computation of energy assessment. The tool is at present undergoing testing to test the effectiveness in the design process.

Acknowledgements

The Australian Research Council for funding this project.

Dr Nick Baker and Professor Peter Woods for advice and comment on the use of the LT Method in tropical climates

Mr Michael Docherty for comment on the potential of ventilation based models in the development of the LT information package.

Dr Steve Szokolay for his work on the architectural science issues concerning the project.

Dr Ian Edmonds for his contribution to the discussion on lighting design.

References

1. HYDE, R.A, 'A Lighting Thermal and Ventilation (LTV) Design Tool for Tall Buildings in Tropical and Subtropical Regions,' in the proceedings of the *International Conference on Tall Buildings and Urban Habitat*, University of Technology Malaysia, Malaysia, May, Vol. 2, Section 1B, 1999A, pp. 64-70.

2. GOULDING, J.R. et al, *Energy in Architecture. The Passive Solar Handbook*, Commission of the European Communities, University College Dublin, 1993, p.3.

3. Ibid. p.264.

4. EDMONDS, I., *Advanced Day lighting Systems for the Tropics and Subtropical Climates*. Unpublished paper, School of Physics, Queensland University of Technology.

5. BAKER, N. V. & STEEMERS, K., (1995), *LT Method 2.0 An energy design tool for non-domestic buildings*. Available from - BRECSU. Building Research Establishment, Garston, Watford .WD2 7JR.

6. BAKER, N. V. & STEEMERS, K., (1996), *LT Method 3.0 - a strategic energy design tool for Southern Europe*. Energy and Buildings, 23, 1996, p.251 - 256.

7. HYDE, R.A., and PEDRINI, A., (1999) 'An Architectural Design Tool (LTV) for Non-domestic Buildings in Tropical and Sub-tropical Regions: Critique of the Solar Design Strategies for Energy Efficiency,' in the *Proceedings of Solar 99*, Deakin University, 1-4 December, CD entry.

8. HYDE R.A, (1997) 'A Lighting, Thermal and Ventilation (LTV) Design Tool for Non-Domestic Buildings in Tropical and Subtropical Regions: Preliminary Assessment of Design Integration,' in the proceedings of the *31st Conference of the Australian and New Zealand Architectural Science Association 1997*, Brisbane, pp.41-48.

9. HYDE R.A, (1998) 'A Lighting, Thermal and Ventilation (LTV) Design Tool for Non-Domestic Buildings in Tropical and Subtropical Regions: Preliminary Assessment of Design Integration,' in the proceedings of the *31st Conference of the Australian and New Zealand Architectural Science Association 1997*, Brisbane, pp. 41-48.

10. WINKELMANN, F. C., BRIDSALL, B. E., BUHL, W. F., ELLINGTON, K. L. and ERDEM, A. E., (1993), 'DOE-2 Supplement Version 2.1E. LBL-34947,' November. [810 pages approx.].